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SEAKEEPING CHARACTERISTICS FOR FOUR REPRESENTATIVE U.S. COAST GUARD CUTTERS

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Introduction

It is a fact that despite naval architectural design procedures in common use as recent as the last few years, it is almost impossible to adequately evaluate the effectiveness of any ship system without taking into account ship motions resulting from interaction with the seaway. The neglect of this area of consideration was a result of the inadequacy of state-of-the-art applied hydrodynamics to predict motion responses of a ship to a seaway and confusion as to how such predictions, which must by their very nature be statistical, could be presented. Due to several landmark investigations, methods now exist which allow the designer to make statistical predictions of ship motions in a seaway and, as such, use them in evaluations on the adequacy of a design effort. This study makes use of one of these methods in order to arrive at predictions of motion responses for four representative cutters so that the impact of this motion on helicopter designs proposed to be mated with these cutters may be investigated.

Technical Approach

Motion predictions were made for four representative U.S. Coast Guard vessels. These were the RESOLUTE Class WMEC, the HAMILTON Class WHEC, the POLAR STAR Class WAGB and the new 270 foot class WMEC. These were done by use of the MIT ~~Massachusetts Institute of Technology~~ Five Degree-of-Freedom Seakeeping Prediction Program as modified by the Naval Ship Engineering Center, ~~Code 6136~~. The root-mean-square (rms) values for yaw, sway, pitch and heave displacement as well as vertical displacement, velocity and acceleration at the center of each ship's landing circle were taken directly from the output of the program. These values have correlated well with other seakeeping programs as well as full-scale values and seem reasonable for the ships studied. The roll values, however, were extremely sensitive to the shape of the sea spectra and its modal frequency since the RAO's for roll responses had extremely sharp peaks at resonance. As a result the roll valves predicted by the MIT program using the standard Pierson-Moskowitz one-parameter spectrum were unrealistically low when compared to known roll values for the vessels under consideration. It was found, however, that if spectra were used based on the extensive work done by Ochi and Hubble in reference (1), excellent correlation was obtained between predictions and known values. Thus, the RAO's for roll displacement, velocity and acceleration were calculated using the MIT program, and the responses obtained by operating with these over the "most probable spectrum" for each sea state. This spectrum was determined by Ochi and Hubble after analysis of 800 different recorded spectrum gathered in the North Atlantic.

SHIP PARTICULARS

Table I presents the most important particulars of the four ships.

TABLE I

SHIP PARTICULARS	USCGC HAMILTON	270 FOOT WMEC	USCGC RESOLUTE	USCGC POLAR STAR
Length Between Perpendiculars (FT)	350	255	200	352
Maximum Beam (FT)	42	38	33	78
Draft Amidships (FT)	14.47	3.45	10.24	31.48
Displacement (Long Tons)	3043	1722.	1008.7	13,093
KG (FT)	17.22	16.94	15.12	26.06
GM (FT) Corrected for Free Surface	2.34	2.18	2.37	10.02
LCG (From FP) (FT)	185.03	130.34	102.45	173.47
Roll Radius of Gyration (Percentage of Maximum Beam	.41	.40	.48	.40
Yaw Radius of Gyration (Percentage of LBP-as Estimated)	.25	.25	.25	.25
Bilge Keels	YES	YES	YES	NO
Roll Fins (Not Considered in Operation)	NO	YES	NO	NO
Location of Helicopter Landing Platform-Point where motions calculated				
FT From FP	275	180	133	300
HT Above Baseline	20.5	31.5	17.13	24.5

Sea Spectra

It was decided to choose three representative sea states, ranging from light to heavy seas, in which cutters were likely to find themselves operating. Those chosen were sea states 3, 5 and 7. Figures 1 through 3 show the spectra used. Note that the dashed line spectrum is the Pierson-Moskowitz spectrum used in predicting all responses other than roll while that marked most probable spectrum was chosen for roll calculations.

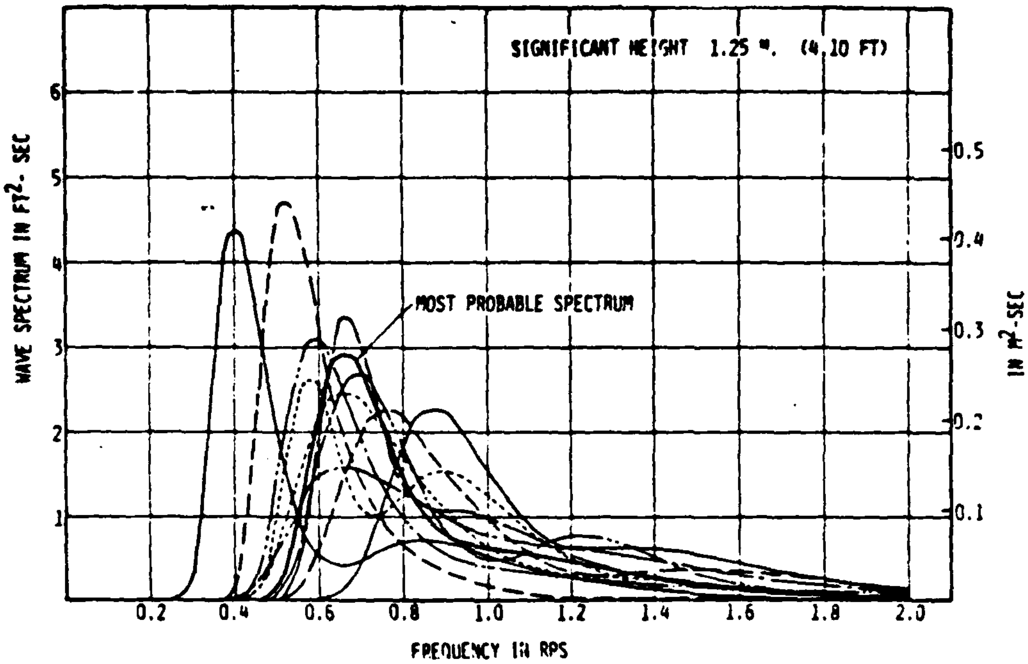

Figure 1

Sea State 3 Spectra

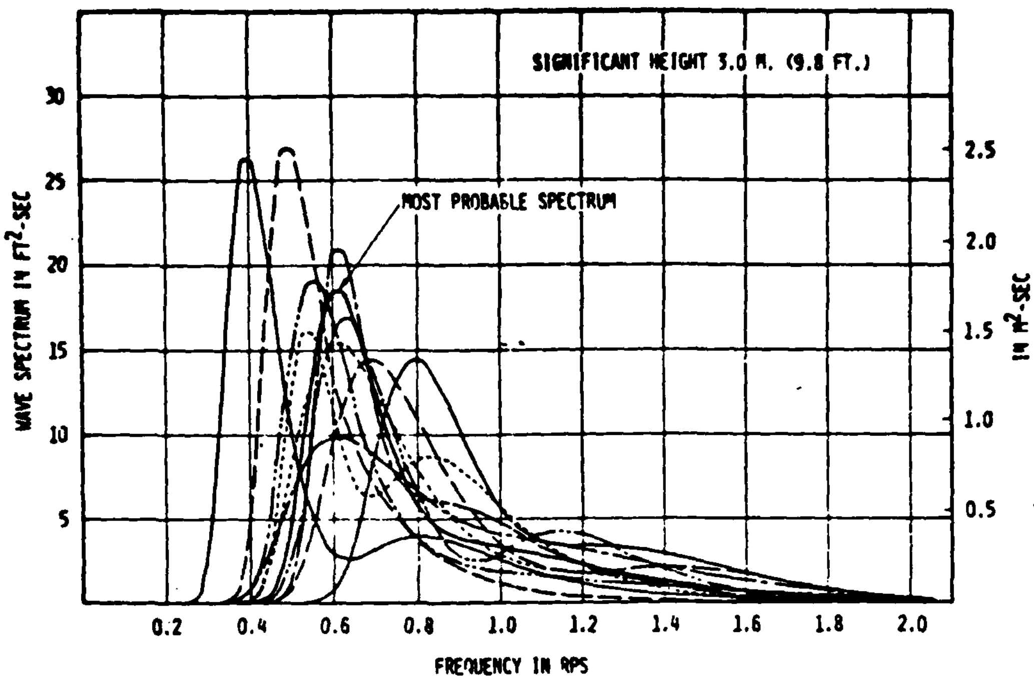

Figure 2
Sea State 5 Spectra

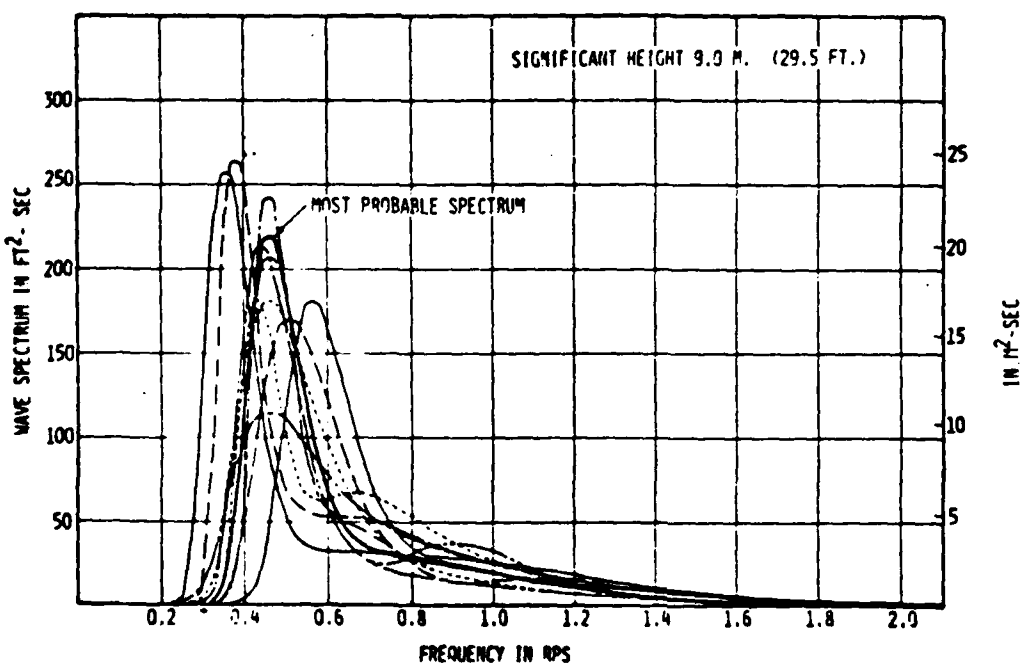

Figure 3
Sea State 7 Spectra

Results

Table II presents the predicted rms values for the ships motions. It should be noted that the valves recorded here are those for worst heading for each particular component of motion. Another point of consideration is that these predictions are based on long-crested irregular seas, consisting of wave components of varying frequencies with parallel wavefronts. It can be argued that a more natural representation is a short-crested sea where the spectral energy is spread over waves approaching the ship at angles which vary from the pricipal sea direction. However, long-crested seas are not rare and the motions which result from their excitation are somewhat more severe than those resulting from excitation by short-crested seas. Thus, to be conservative, it would be prudent to use those values predicted for encounters with long-crested waves.

CUTTER	SPEED (KTS)	SEA STATE	ROLL DISPLACEMENT (DEG)	ROLL VELOCITY (DEG/SEC)	ROLL ACCELERATION (DEG/SEC²)	YAW DISPLACEMENT (FT)	SWAY DISPLACEMENT (FT)	HEAVE DISPLACEMENT (FT)	PITCH DISPLACEMENT (DEG)	TOTAL VERTICAL MOTION (FT)	TOTAL VERTICAL VELOCITY (FT/SEC)	TOTAL VERTICAL ACCELERATION (FT/SEC²)	ROLL PERIOD (AVG) (SEC)	PITCH PERIOD (AVG) (SEC)
210 FOOT WMEC	5	3	2.35	1.96	1.65	.09	.52	.22	.32	.39	.35	.34	8.98	6.91
	5	5	5.34	4.42	3.67	.16	2.04	1.55	1.49	2.13	1.43	1.02	9.14	8.88
	5	7	11.20	8.73	6.95	.52	7.45	6.73	3.27	7.48	3.56	1.92	10.12	10.98
	10	3	2.17	1.81	1.52	.09	.52	.20	.30	.37	.26	.19	8.99	9.08
	10	5	5.00	4.12	3.42	.14	2.04	1.47	1.43	2.02	1.16	.68	9.19	10.55
	10	7	10.94	8.46	6.69	.48	7.45	6.64	3.20	6.56	2.67	1.16	10.27	12.63
	15	3	2.04	1.70	1.43	.09	.52	.20	.31	.37	.19	.15	8.99	12.09
	15	5	4.75	3.91	3.24	.17	2.06	1.42	1.40	1.95	.93	.45	9.21	12.86
	15	7	10.72	8.25	6.20	.61	7.46	6.56	3.17	7.23	2.74	1.10	10.36	14.60
400 FOOT WAGB	5	3	1.19	.94	.75	.03	.33	.27	.08	.27	.27	.27	9.92	5.96
	5	[illegible]	3.58	2.76	2.15	.23	1.64	1.08	.48	1.08	.70	.53	10.47	9.95
	5	[illegible]	13.52	9.66	6.88	2.36	10.92	6.30	1.86	6.30	2.72	1.28	12.16	13.15
	10	3	1.19	.94	.75	.04	.34	.42	.10	.42	.33	.26	9.92	8.27
	10	5	3.58	2.76	2.15	.30	1.71	1.19	.51	1.19	.69	.44	10.47	11.42
	10	7	13.59	9.70	7.01	2.59	11.28	6.32	1.91	6.32	2.50	1.06	12.18	14.43
	15	3	1.19	.94	.75	.04	.36	.31	.09	.31	.15	.08	9.92	13.02
	15	5	3.58	2.76	2.15	.33	.79	1.18	.53	1.18	.54	.25	10.47	13.53
	15	7	13.66	9.74	7.03	2.77	11.97	6.33	1.97	6.33	2.29	.86	12.21	16.60
270 FOOT WMEC	5	3	1.68	1.35	1.10	.09	.43	.20	.19	.28	.24	.22	9.64	7.45
	5	5	3.39	2.62	2.05	.17	1.65	1.31	1.09	1.67	1.10	.75	10.37	9.32
	5	7	15.35	11.20	8.30	.28	6.73	6.44	2.85	7.01	3.26	1.68	11.62	11.59
	10	3	1.67	1.34	1.09	.10	.43	.18	.18	.25	.17	.12	9.64	9.33
	10	5	4.85	3.79	2.99	.17	1.66	1.24	1.05	1.59	.89	.51	10.19	10.83
	10	7	15.39	11.16	8.27	.29	6.75	6.34	2.82	6.90	2.88	1.30	11.63	13.10
	15	3	1.68	1.35	1.09	.09	.40	.15	.16	.22	.12	.09	9.65	12.10
	15	5	4.82	3.77	2.97	.18	1.77	1.29	1.07	1.63	.77	.36	10.19	13.06
	15	7	15.28	11.13	8.24	.29	6.89	6.40	2.81	6.92	2.57	1.01	11.65	15.07
378 FOOT WMEC	5	3	2.27	1.80	1.43	.09	.40	.15	.07	.16	.14	.14	9.96	6.51
	5	5	6.41	5.01	3.94	.18	1.60	1.11	.64	1.16	.72	.47	10.22	9.94
	5	7	15.51	11.65	8.85	.31	6.67	6.28	2.30	6.38	2.81	1.35	11.00	12.77
	10	3	2.30	1.82	1.45	.09	.40	.14	.08	.15	.11	.08	9.96	8.70
	10	5	6.52	5.09	4.00	.18	1.60	1.05	.62	1.09	.59	.32	10.25	11.37
	10	7	15.79	11.87	9.01	.33	6.71	6.15	2.26	6.25	2.50	1.07	11.00	14.19
	15	3	2.36	1.86	1.48	.09	.40	.15	.08	.15	.08	.06	10.02	12.53
	15	5	6.74	5.25	4.12	.18	1.61	1.00	.60	1.04	.45	.22	10.28	13.51
	15	7	16.32	12.28	9.32	.33	6.75	6.04	2.23	6.14	2.22	.94	11.00	15.90

TABLE II
Predicted Cutter Motions
(RMS Values)

Responses at Helicopter Landing Point in Long-crested Irregular Seas..

As noted above, the values given in Table II are rms valus. As it is reasonable to assume a Gaussian or normal distribution for the random response spectra. Several interesting statistical inferences can be made using these values. These are values which give the highest expected amplitude in a specific number of cycles of responses or the average of a specific number of the highest amplitudes. These values are given in Table III.

Table III

SINGLE AMPLITUDE STATISTICS

STATISTIC		MULITIPLIER (OPERATED ON RMS VALVE)
Root Mean Square		1.00
Average Amplitude		1.25
Average of Highest One-Third Amplitudes		2.00
Average of Highest One-Tenth Amplitudes		2.55
Average of Highest One-Hundredth Amplitudes		3.34
Average of Highest One-Millionth Amplitudes		5.27
Highest Expected Amplitude in Indicated Number of Cycles of Response ---		
	10	2.15
	30	2.61
	50	2.80
	100	3.03
	200	3.25
	1000	3.72

REFERENCES

1. Ochi, M.K. and N. Hubble," On Six Parameter Wave Spectra" , Proceedings of the Fifteenth Conference on Coastal Engineering, July,1976.

5441

DEPARTMENT OF TRANSPORTATION U. S. COAST GUARD CGHQ-3844 (Rev. 5-68)	NAVAL ENGINEERING DIVISION REQUEST FOR TECHNICAL SERVICES		
JOB ORDER NUMBER 5041	STATUS ☐ APPROVED FOR PILOT INST. ☐ ADDITIONAL INFORMATION REQUIRED ☐ APPROVED FOR SHIPALT		
ORIGINATOR OSR/Industry		NAME CHATTERTON	
SUBJECT (Class) WHEC/WMEC/WAGB	CASE NUMBER	CATEGORY AND FILE NUMBER 9000	DATE 6 April 77

STATEMENT OF PROBLEM

Generate helicopter flight deck motions data for cutters, for use in establishing helicopter design criteria for industry use in SRR helo procurement.

SUGGESTED SOLUTION: (Include indication of quality desired by including life expectancy, cost information)

Use MIT 6 degree of freedom program to generate desired data. Provide data to EAE project officer for SRR to ensure distribution to all competitors.

JOB ORDER NUMBER	DATE RECEIVED	CHIEF, DESIGN BRANCH
	4/7	

Reverse of CGHQ-3844 (Rev. 5-68)

PERTINENT INFORMATION: (Include technical data and observation from personal visit to ship of class)

TYPE OF SERVICE REQUESTED:

- [ ] PLANS-WORKING, PILOT, SKETCH
- [ ] SPECIFICATIONS-CONTRACT, PURCHASE, WORK LIST
- [ ] PREPARATION OF SHIP ALTERATION
- [x] XX CALCULATIONS OR ANALYSIS
- [ ] ESTIMATED COST

INFORMATION REQUIRED BY	CHIEF
1 May 1977	Chatterton

CASE ASSIGNED:

- [ ] BOAT
- [ ] ELECTRICAL
- [x] XX SD
- [ ] HULL
- [ ] MACHINERY

REMARKS:

DATE	CHIEF, DESIGN BRANCH
4/7	[illegible signature]

CASE ASSIGNED: Ashe

REMARKS

Requested data forwarded by memo G-ENE-5D/64 9000 ser 585 of 19 May 1977

DATE	CHIEF, TECHNICAL SECTION

- [ ] INFORMATION FORWARDED AS REQUESTED
- [ ] INFORMATION CANNOT BE FURNISHED FOR THE FOLLOWING REASONS:

DATE	CHIEF, DESIGN BRANCH

COUPON - DO NOT USE THIS SPACE